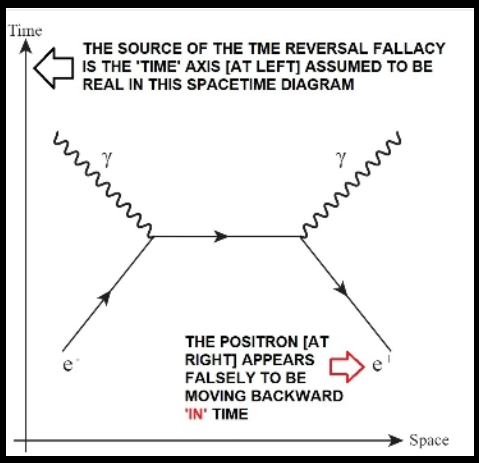

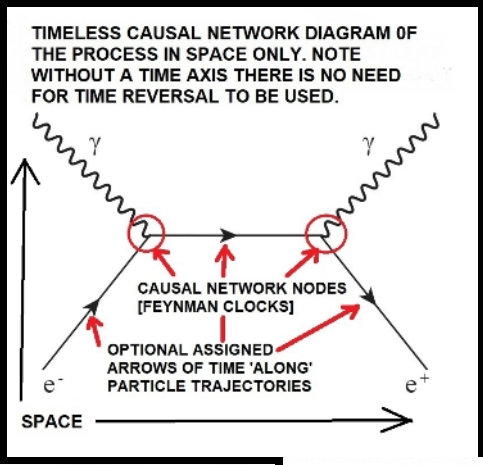

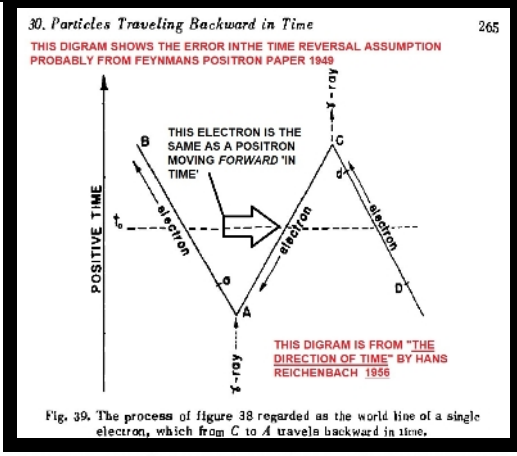

Fig. 39. The process of figure 38 regarded as the world line of a single electron, which from C to A travels backward in time.

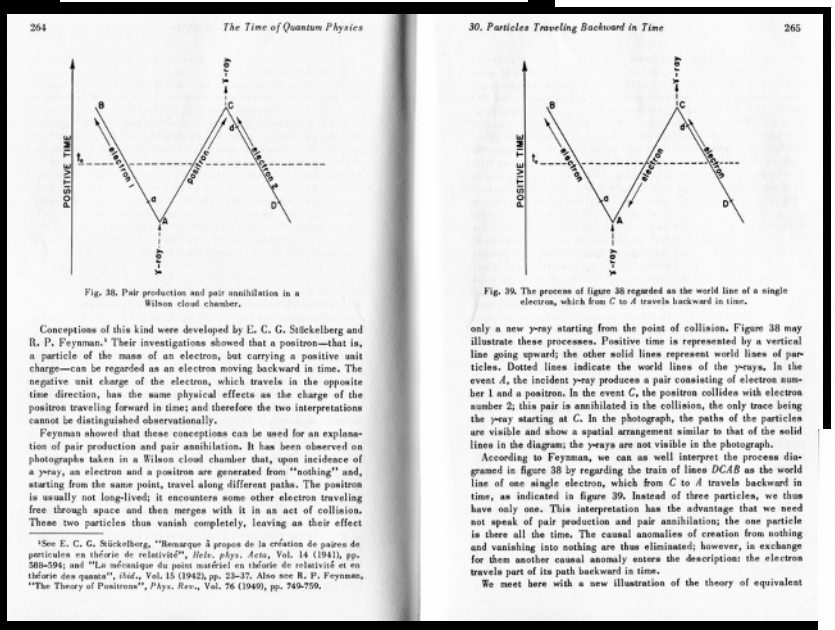

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Fig. 38. Pair production and pair annihilation in a Wilson cloud chamber.

Conceptions of this kind were developed by E. C. G. Stückelberg and R. P. Feynman.[1] Their investigations showed that a positron—that is, a particle of the mass of an electron, but carrying a positive unit charge—can be regarded as an electron moving backward in time. The negative unit charge of the electron, which travels in the opposite time direction, has the same physical effects as the charge of the positron traveling forward in time; and therefore the two interpretations cannot be distinguished observationally.

Feynman showed that these conceptions can be used for an explanation of pair production and pair annihilation. It has been observed on photographs taken in a Wilson cloud chamber that, upon incidence of a γ-ray, an electron and a positron are generated from "nothing" and, starting from the same point, travel along different paths. The positron is usually not long-lived; it encounters some other electron traveling free through space and then merges with it in an act of collision. These two particles thus vanish completely, leaving as their effect

[1] See E. C. G. Stückelberg, "Remarque à propos de la création de paires de particules en théorie de relativité", *Helv. phys. Acta*, Vol. 14 (1941), pp. 588-594; and "La mécanique du point matériel en théorie de relativité et en théorie des quanta", *ibid.*, Vol. 15 (1942), pp. 23-37. Also see R. P. Feynman, "The Theory of Positrons", *Phys. Rev.*, Vol. 76 (1949), pp. 749-759.

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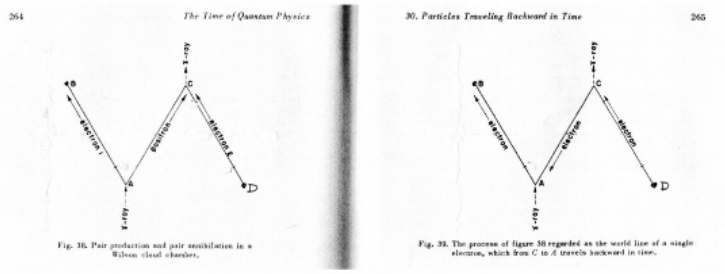
Fig. 39. The process of figure 38 regarded as the world line of a single electron, which from C to A travels backward in time.

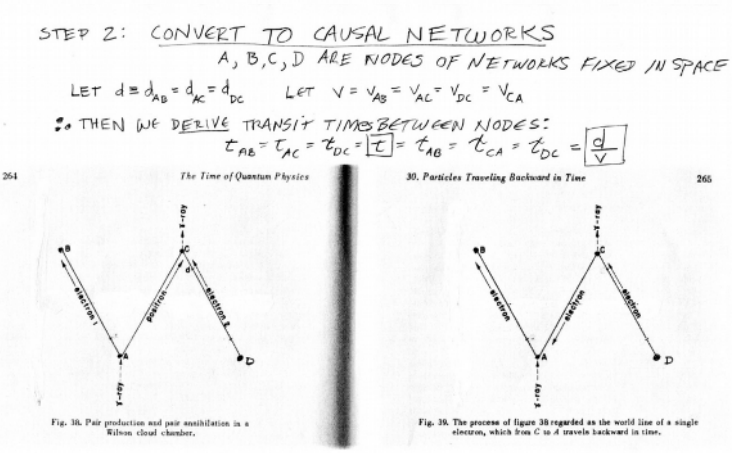
only a new γ-ray starting from the point of collision. Figure 38 may illustrate these processes. Positive time is represented by a vertical line going upward; the other solid lines represent world lines of particles. Dotted lines indicate the world lines of the γ-rays. In the event A, the incident γ-ray produces a pair consisting of electron number 1 and a positron. In the event C, the positron collides with electron number 2; this pair is annihilated in the collision, the only trace being the γ-ray starting at C. In the photograph, the paths of the particles are visible and show a spatial arrangement similar to that of the solid lines in the diagram; the γ-rays are not visible in the photograph.

According to Feynman, we can as well interpret the process diagramed in figure 38 by regarding the train of lines $DCAB$ as the world line of one single electron, which from C to A travels backward in time, as indicated in figure 39. Instead of three particles, we thus have only one. This interpretation has the advantage that we need not speak of pair production and pair annihilation; the one particle is there all the time. The causal anomalies of creation from nothing and vanishing into nothing are thus eliminated; however, in exchange for them another causal anomaly enters the description: the electron travels part of its path backward in time.

We meet here with a new illustration of the theory of equivalent

STEP 1 : REMOVE TIME FROM SPACE-TIME LEAVING JUST SPACE





STEP 2: CONVERT TO CAUSAL NETWORKS

A, B, C, D ARE NODES OF NETWORKS FIXED IN SPACE

LET $d \equiv d_{AB} = d_{AC} = d_{DC}$ LET $V = V_{AB} = V_{AC} = V_{DC} = V_{CA}$

∴ THEN WE DERIVE TRANSIT TIMES BETWEEN NODES:

$t_{AB} = t_{AC} = t_{DC} = \boxed{t} = t_{AB} = t_{CA} = t_{DC} = \boxed{\frac{d}{V}}$

NOTE THAT THE POSITRON (FIG 38) IS MOVING FROM A TO C IN SPACE ONLY IN A DIRECTION OPPOSITE TO THE ELECTRON (FIG 39) FROM C TO A. WITHOUT TIME CONFUSING THE DIAGRAMS, THE TIME REVERSAL INTERPRETATION IS NOT NEEDED. TIME IS A DERIVED CONCEPT, NOT FUNDAMENTAL LIKE SPACE.